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Ando

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(54) PLANE-TYPE SPEAKER AND AV APPARATUS

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(30) **Foreign Application Priority Data**

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H04R 17/00 (2006.01)
H04R 7/10 (2006.01)
(Continued)

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CPC ***H04R 17/00*** (2013.01); ***H04R 7/045*** (2013.01); ***H04R 7/10*** (2013.01); ***H04R 17/005*** (2013.01); *H04R 7/18* (2013.01); *H04R 2307/025* (2013.01); *H04R 2499/15* (2013.01)

(58) **Field of Classification Search**
CPC H04R 17/00; H04R 17/005; H04R 17/02; H04R 17/025; H04R 17/10; H04R 7/12; H04R 7/122; H04R 7/125; H04R 7/127; H04R 2440/00; H04R 2440/01; H04R 2440/05; H04R 2440/07; H04R 2217/01; H01L 41/08; H01L 41/0805; H01L 41/083; H01L 41/0926; H01L 41/0973; H01L 41/098
USPC 381/190, 191, 423, 426, 430, 431, 381/386–388, 394, 395, 173; 181/157, 161, 181/167–173; 310/311, 321, 322, 328, 334
See application file for complete search history.

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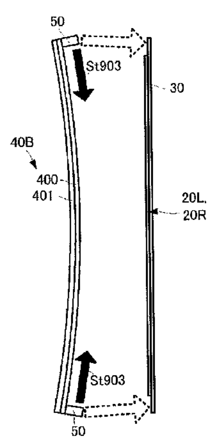
(57) **ABSTRACT**

A plane-type speaker where, on one of the main surfaces of an exciter film, there are placed piezoelectric films which are expanded and contracted by sound-releasing driving signals applied thereto. An oscillation plate is secured to the excited film through frame members. The oscillation plate has a flat-plate shape and is secured to the exciter film while having a warped shape such that it is gradually spaced further away from the exciter film, with decreasing distance from the secured ends to a center area, when viewed at a side surface. This realizes a state where the exciter film is pulled outwardly with respect to the secured ends due to bending stresses therein. If sound-releasing driving signals are applied to the piezoelectric films in this state, the exciter film contracts and expands along with the expansion and contraction of the piezoelectric films, thereby causing the oscillation plate to oscillate.

12 Claims, 12 Drawing Sheets



(51) **Int. Cl.**
H04R 7/04 (2006.01)
H04R 7/18 (2006.01)

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FIG. 1

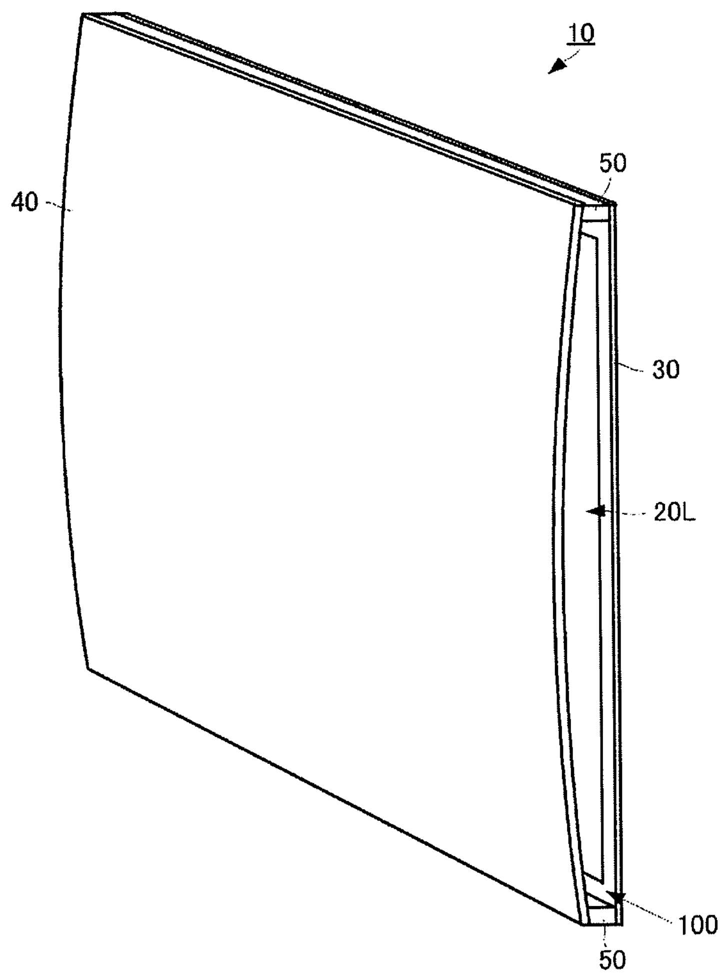


FIG. 2(A)

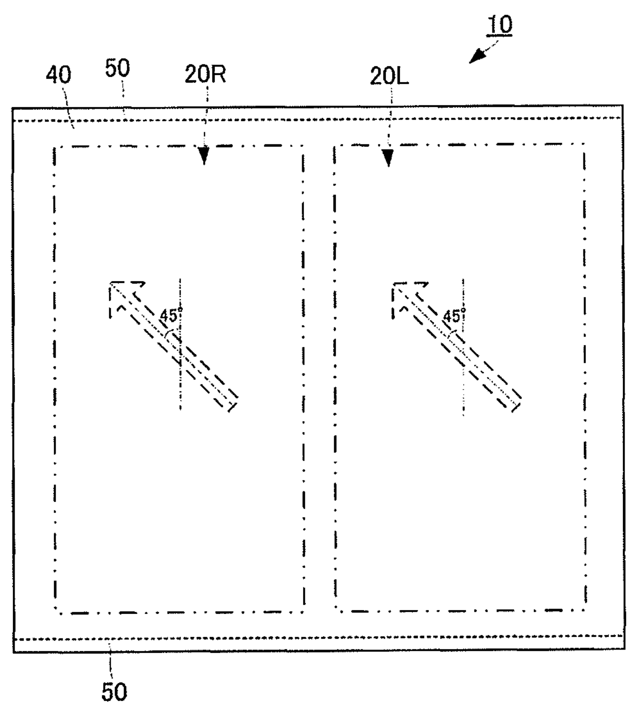


FIG. 2(B)

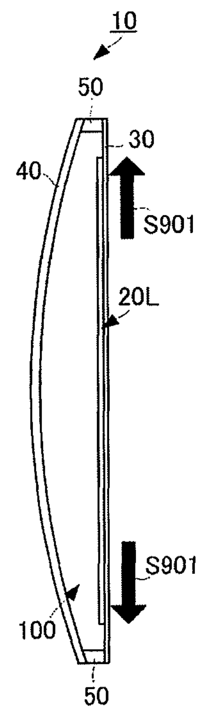


FIG. 3

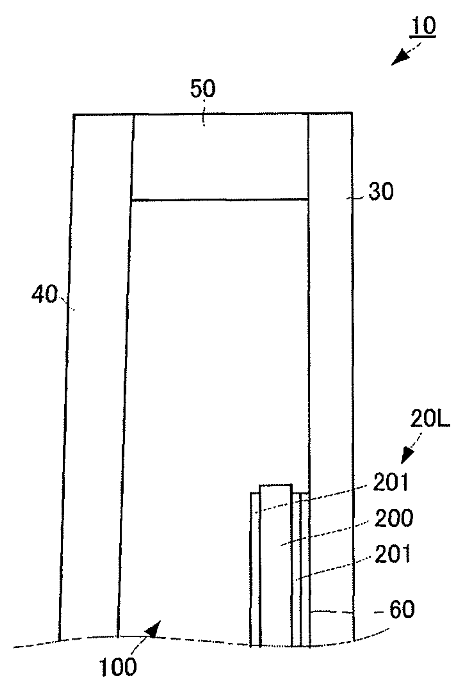


FIG. 4(A)

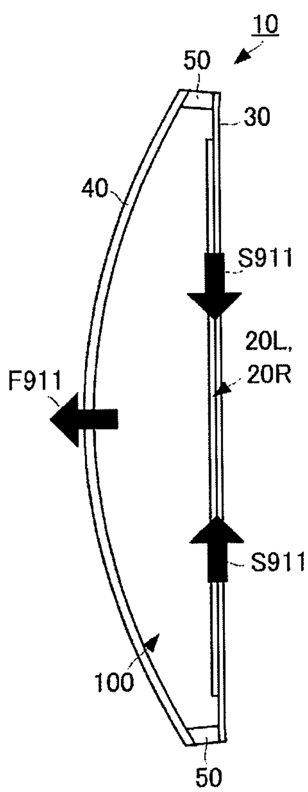


FIG. 4(B)

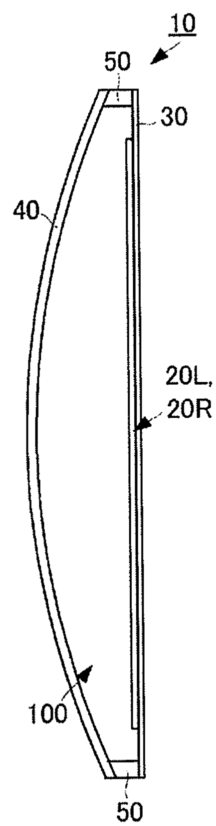


FIG. 4(C)

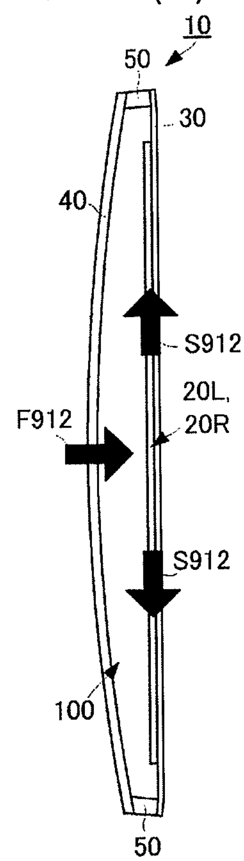
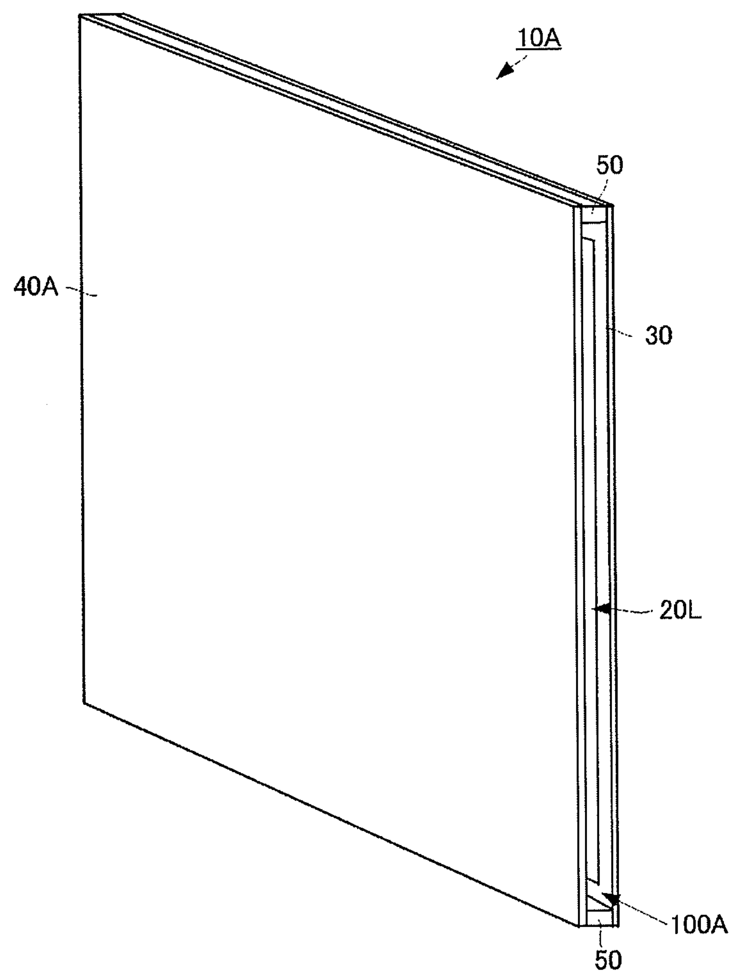
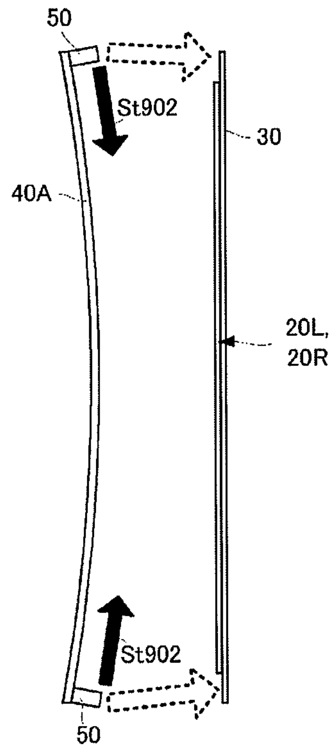


FIG. 5

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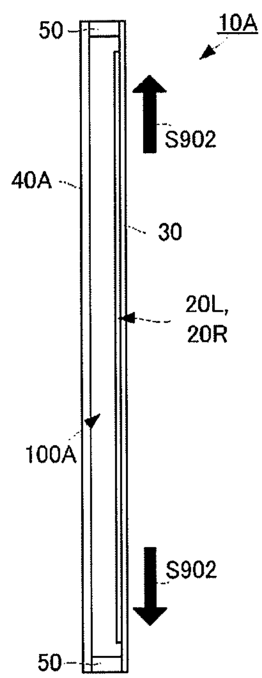
St902
30
40A
20L,
20R
St902
50

FIG. 6(A)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40A
30
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20R
100A
S902
50

FIG. 6(B)

FIG. 7

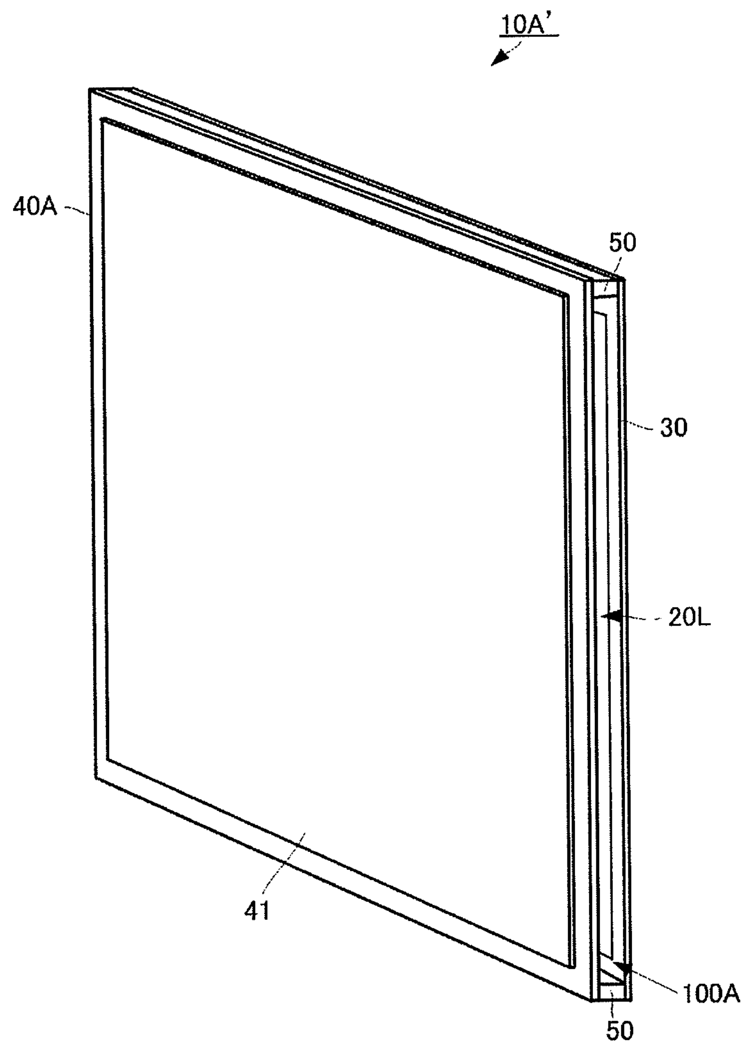
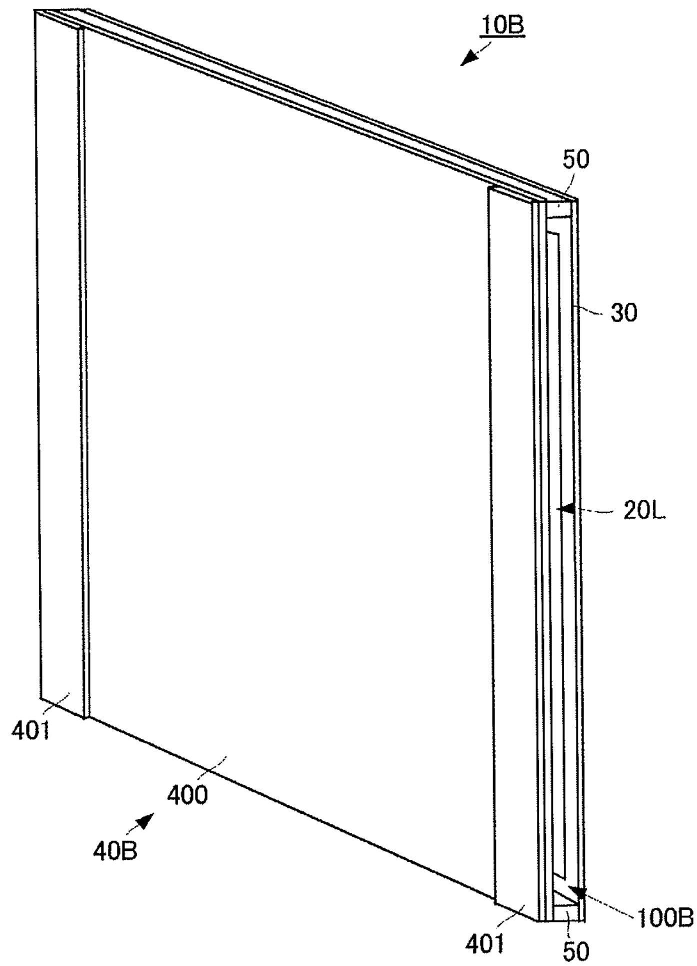


FIG. 8



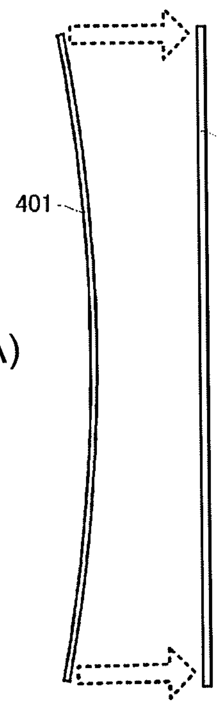


FIG. 9(A)

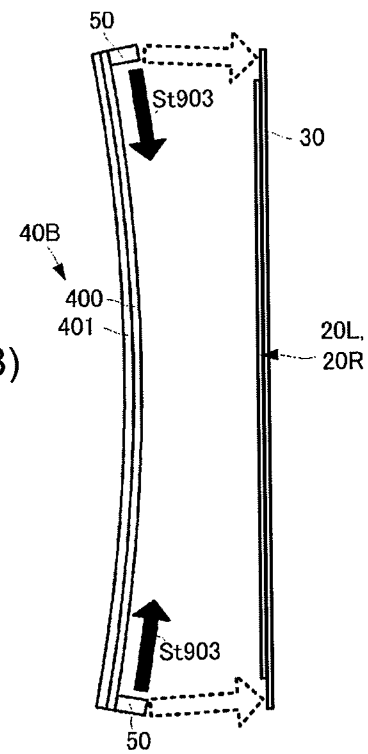


FIG. 9(B)

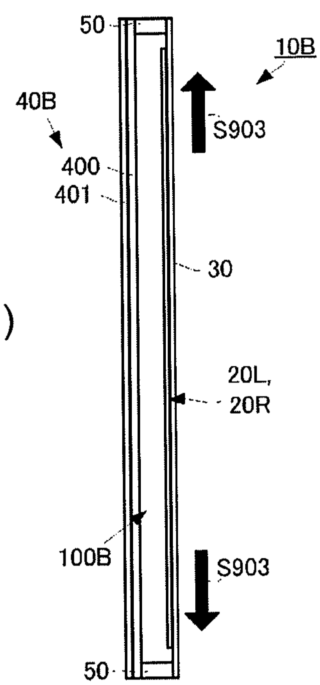


FIG. 9(C)

FIG. 10

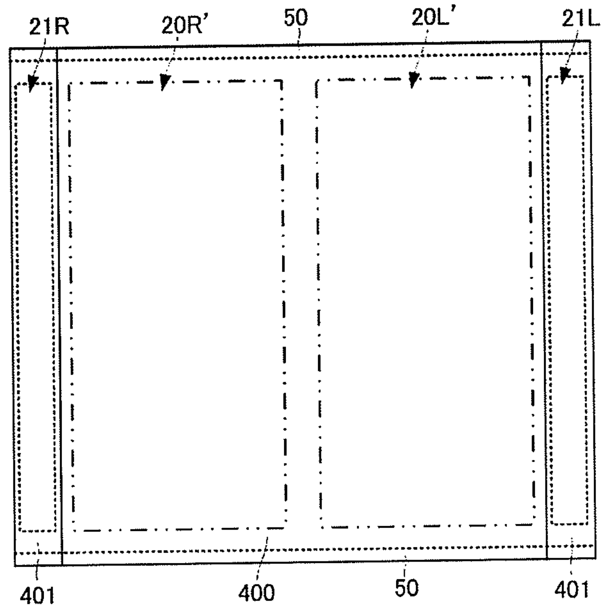


FIG. 11

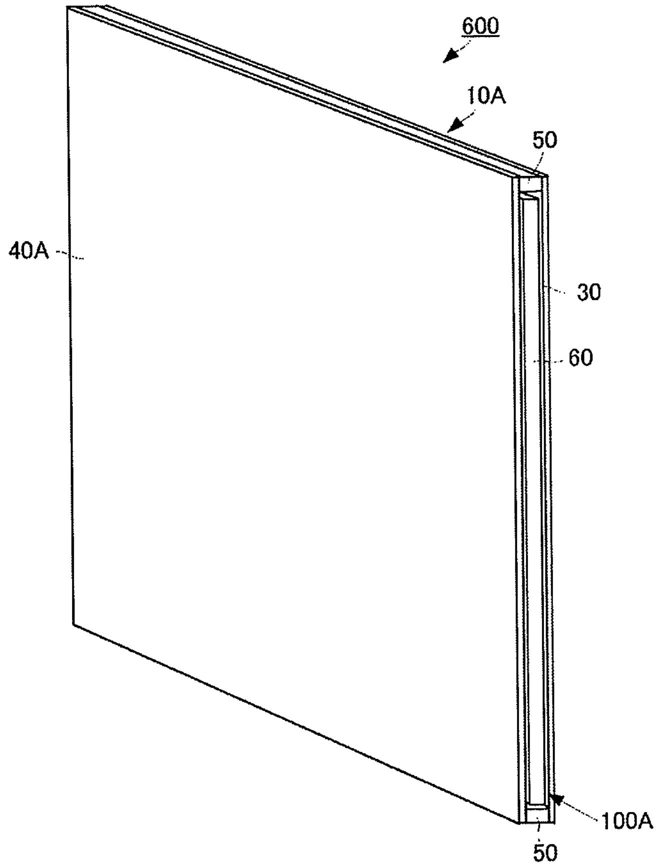


FIG. 12(A)

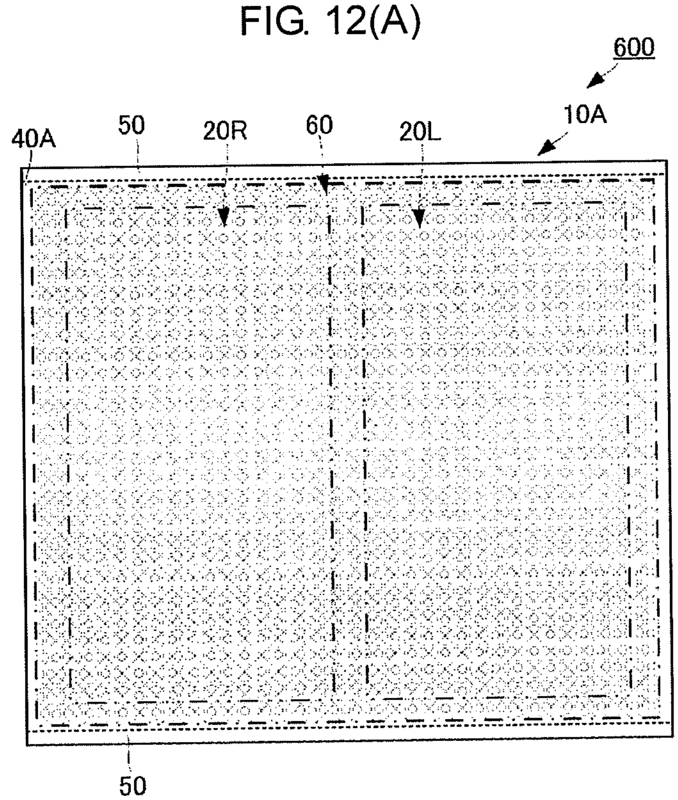


FIG. 12(B)

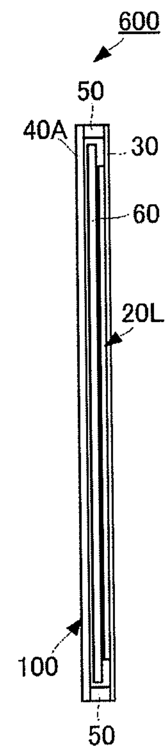


FIG. 13(A)

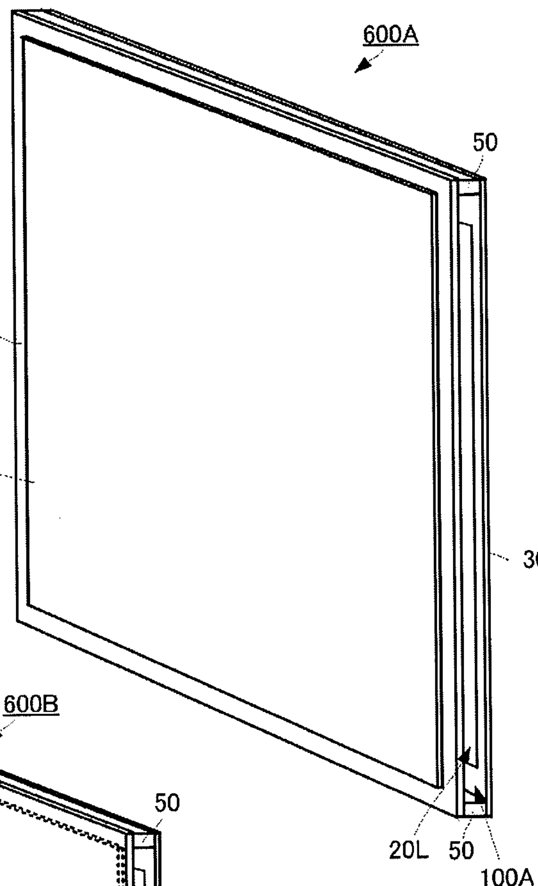


FIG. 13(B)

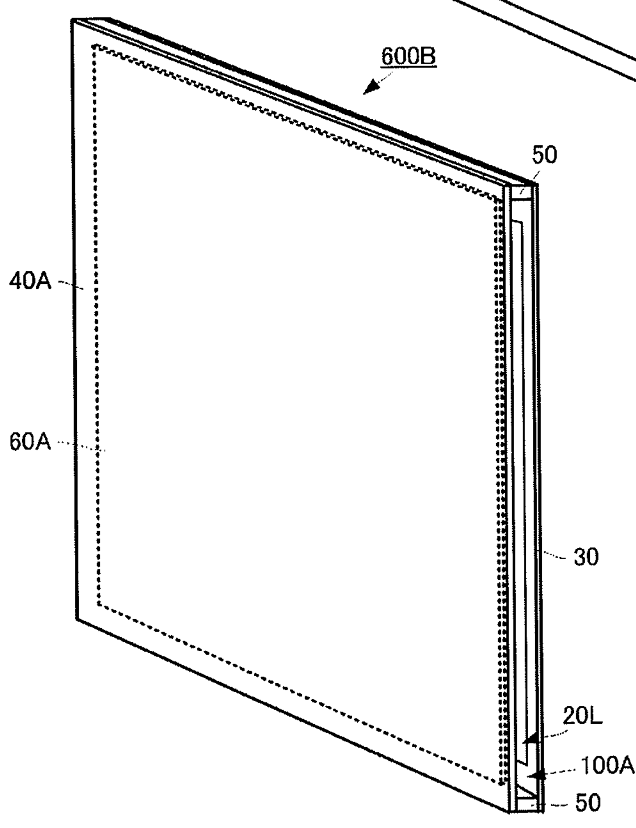
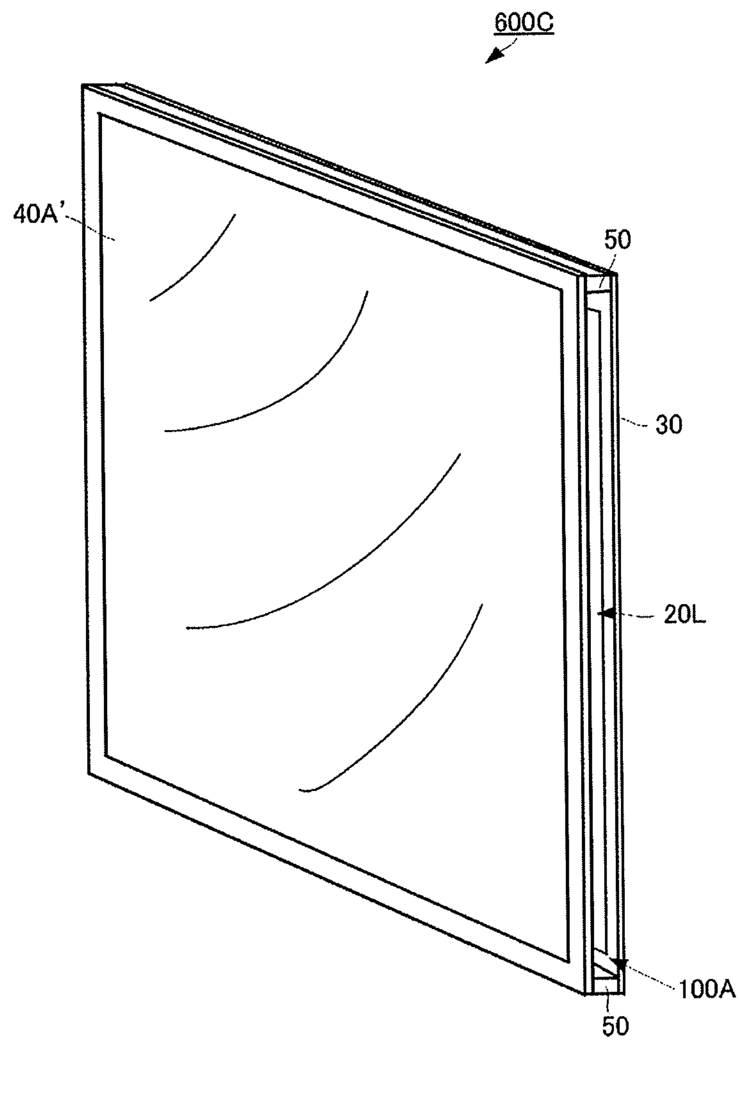


FIG. 14



PLANE-TYPE SPEAKER AND AV APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of application Ser. No. 14/081,150, filed Nov. 15, 2013, which is a continuation of International application No. PCT/JP2012/062578, filed May 17, 2012, which claims priority to Japanese Patent Application No. 2011-110156, filed May 17, 2011, the entire contents of each of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to piezoelectric speakers employing polymer sheets with piezoelectricity.

BACKGROUND OF THE INVENTION

In recent years, there have been increasing demands for thin-type speakers, for the reason that they should be mounted in thin-type displays, and the like. Therefore, various types of thin-type speakers have been contrived.

Patent Document 1 describes a speaker structured to have a flat-plate type PolyVinylidene DiFluoride (PVDF), and electrodes formed on the opposite main surfaces thereof.

However, such conventional thin-type speakers have had the drawback of poor sound-quality characteristics, in general, since they cannot have larger depthwise sizes as in dynamic speakers.

In order to overcome this drawback, for example, a speaker in Patent Document 2 is adapted to oscillate a flat-plate type membrane made of a resin and the like, through an electromagnetic type exciter (actuator). The speaker in Patent Document 1 has an electromagnetic-type exciter which is mounted to a side surface of a membrane.

Further, a speaker in Patent Document 3 is adapted to have two flat plates placed with a predetermined interval interposed therebetween, and electromagnetic-type exciters (actuators) placed in a hollow area between these flat plates, such that the flat plates are oscillated by these exciters.

Patent Document 1: JP-A No. 2009-272978

Patent Document 2: JP-A No. 62-73898

Patent Document 3: JP-A No. 2005-117217

SUMMARY OF THE INVENTION

The speaker described in the aforementioned Patent Document 2 is provided with the electromagnetic-type exciter beside the membrane and, therefore, is shaped to have a size increased by an amount corresponding to the exciter placed therein.

Further, the speaker described in Patent Document 3 is required to have at least a thickness necessary for the exciters, since the exciters are placed between the flat plates. Further, since the exciters are placed at the opposing both ends of the flat plates, the flat plate surfaces are required to have an area increased by at least an amount necessary for the two exciters.

Accordingly, it is an object of the present invention to provide a plane-type speaker which has excellent sound-quality characteristics while having a smaller thickness and, further, has a size with substantially only an area of an oscillation surface.

A plane-type speaker according to the present invention includes a piezoelectric film, an exciter film, and an oscillation plate. The piezoelectric film is made of a piezoelectric

resin provided with electrodes formed on its opposite main surfaces. The exciter film is formed from a flat plate having a main surface such that the piezoelectric film is mounted substantially entirely on the main surface thereof. The oscillation plate is secured to the exciter film, in a state where it is warped in a direction orthogonal to the main surface of the exciter film.

With this structure, the exciter film is caused to expand and contract, along with the expansion and contraction of the piezoelectric film due to a sound-releasing driving signal applied thereto. Due to the expansion and contraction of the exciter film, the oscillation plate is oscillated in the direction orthogonal to its main surface. Since the piezoelectric film is mounted on substantially the entire surface of the exciter film, the exciter film is effectively expanded and contracted due to the expansion and contraction of the piezoelectric film, which can increase the oscillation stroke of the oscillation plate. This improves the low-tone output characteristics, thereby improving the sound-quality characteristics. Further, the exciter film has the same shape as that of the oscillation plate when viewed at a front surface and, therefore, does not have an unnecessarily-larger area. Further, the depth size is constituted only by the thicknesses of the flat-plate type oscillation plate and the flat-plate type exciter film, and the depth size of the hollow area between the oscillation plate and the exciter film. Further, the depth size of the hollow area can be made to be the sum of the thickness of the piezoelectric film and the oscillation stroke of the oscillation plate. Accordingly, the depthwise size can be made smaller, namely the thickness of the speaker can be made smaller.

Further, a plane-type speaker according to the present invention includes a piezoelectric film, an exciter film, and an oscillation plate and also can have the following structure. The piezoelectric film is made of a piezoelectric resin provided with electrodes formed on its opposite main surfaces. The exciter film is constituted by a flat plate with a main surface such that the piezoelectric film is mounted substantially entirely on the main surface thereof. The oscillation plate is shaped to have a flat-plate surface which is warped in a state where the oscillation plate is not secured to the exciter film, and the oscillation plate is secured to the exciter film such that the flat-plate surface has a flattened shape with respect to the main surface of the exciter film.

With this structure, even in a state where a bending stress is being applied to the oscillation plate, the front surface of the oscillation plate, namely the front surface of the plane-type speaker, is flattened. This can improve the external appearance thereof, even in the front surface of a thin-type television, for example.

Further, the plane-type speaker according to the present invention preferably has the following structure. The oscillation plate is constituted by a flattened main flat plate, and an auxiliary plate with a smaller width than that of the main flat plate and with higher rigidity than that of the main flat plate, such that the auxiliary plate is mounted to the main flat plate. The auxiliary plate has preliminarily had a warped shape.

With this structure, it is possible to suppress degradation of the bending stress in the oscillation plate over time, due to the use of the auxiliary plate which has higher rigidity than that of the main flat plate and can be maintained at a warped state for a longer time period.

Further, in the plane-type speaker according to the present invention, preferably, the piezoelectric film is divided into a plurality of individual piezoelectric films, in a direction which is parallel with the main surface of the exciter film and, also, is along secured opposite end sides of the exciter film.

With this structure, it is possible to apply different sound-releasing driving signals to the respective individual piezoelectric films. This can realize stereo sounds.

Further, the plane-type speaker according to the present invention preferably has the following structures. The piezoelectric film includes a plurality of individual piezoelectric films which are divided into individual piezoelectric films in an area which is overlaid on the auxiliary plate, and individual piezoelectric films in an area which is not overlaid on the auxiliary plate, in a front view. The piezoelectric resin which forms the individual piezoelectric films in the area overlaid on the auxiliary plate is different from the piezoelectric resin which forms the individual piezoelectric films in the area which is not overlaid on the auxiliary plate.

With this structure, it is possible to oscillate the oscillation plate, through the piezoelectric films made of the different piezoelectric resins in the respective areas.

Further, in the plane-type speaker according to the present invention, the piezoelectric resin can be made of PolyVinylidene DiFluoride. With this structure, it is possible to efficiently oscillate the oscillation plate with respect to the sound-releasing driving signal applied thereto, due to the use of the material with a higher piezoelectric constant as the organic piezoelectric film.

Further, the plane-type speaker according to the present invention preferably has the following structure. The exciter film, the oscillation plate and the electrodes are made of a material with optical transparency. The piezoelectric resin is made of polylactic acid.

With this structure, it is possible to realize a plane-type speaker with higher optical transparency over substantially the entire surface thereof when viewed at the front surface. This can realize a so-called flat-plate type transparent speaker, which is a significantly preferable aspect for placing it on the screen of a thin-type display.

Further, the plane-type speaker according to the present invention preferably has the following structure. The exciter film, the oscillation plate and the electrodes are made of a material with optical transparency. The piezoelectric resin which forms the individual piezoelectric films in the area which is not overlaid on the auxiliary plate is made of a polylactic acid, and the piezoelectric resin which forms the individual piezoelectric films in the area overlaid on the auxiliary plate is made of a PolyVinylidene DiFluoride.

With this structure, it is possible to realize a plane-type speaker with higher optical transparency, in the other area than the area in which the auxiliary plate is placed. Further, due to the use of PolyVinylidene DiFluoride having a higher piezoelectric coefficient in the area provided with the auxiliary plate with higher rigidity, it is possible to efficiently oscillate the oscillation plate with respect to the sound-releasing driving signal applied thereto.

Further, the plane-type speaker according to the present invention preferably includes a sound-absorption member between the oscillation plate and the exciter film.

With this structure, sounds generated toward the exciter film from the oscillation plate, and sounds generated by the exciter film itself are absorbed by the sound-absorption member, which further improves the sound-quality characteristics.

Further, the plane-type speaker according to the present invention can include a flat-plate type touch panel provided on the oscillation plate. With this structure, the plane-type speaker can be provided with touch panel functions.

Further, according to the present invention, it is possible to realize an AV apparatus using the aforementioned plane-type speaker. The AV apparatus includes a flat-plate type image reproduction apparatus provided between the oscillation plate and the exciter film in the plane-type speaker, in addition to the plane-type speaker. With this structure, it is possible to realize an AV apparatus with a smaller thickness and excellent sound-quality characteristics.

Further, according to the present invention, it is also possible to realize an AV apparatus, by providing the aforementioned plane-type speaker therein, and further by providing an image reproduction apparatus on the oscillation plate.

Further, according to the present invention, it is also possible to realize an AV apparatus, by providing the aforementioned plane-type speaker therein, and by constituting the oscillation plate by an image reproduction apparatus.

With these structures, similarly, it is possible to realize an AV apparatus with a smaller thickness and with excellent sound-quality characteristics.

With the present invention, it is possible to realize a thin-type plane-type speaker with excellent sound-quality characteristics and with a size with substantially only an area of an oscillation surface.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. **1** is a perspective view of the external appearance of a plane-type speaker **10**.

FIG. **2**(A) is a front view of the plane-type speaker **10**, and FIG. **2**(B) is a side view of the same.

FIG. **3** is a partially-enlarged side view of the plane-type speaker **10**.

FIGS. **4**(A) to **4**(C) are views for explaining operations of the plane-type speaker **10**.

FIG. **5** is a perspective view of the external appearance of a plane-type speaker **10**A.

FIGS. **6**(A) and **6**(B) are views for explaining the structures of the plane-type speaker **10**A.

FIG. **7** is a perspective view of the external appearance of a plane-type speaker **10**A'.

FIG. **8** is a perspective view of the external appearance of a plane-type speaker **10**B.

FIGS. **9**(A) to **9**(C) are views for explaining the structures of the plane-type speaker **10**B.

FIG. **10** is a view of piezoelectric films in the plane-type speaker **10**B.

FIG. **11** is a perspective view of the external appearance of an AV apparatus **600**.

FIG. **12**(A) is a front view of the AV apparatus **600**, and FIG. **12**(B) is a side view of the same.

FIGS. **13**(A) and **13**(B) are perspective views of the external appearances of AV apparatuses **600**A and **600**B, respectively.

FIG. **14** is a perspective view of the external appearance of an AV apparatus **600**C.

DETAILED DESCRIPTION OF THE INVENTION

A plane-type speaker according to a first embodiment of the present invention will be described, with reference to the drawings. FIG. **1** is a perspective view of the external appearance of the plane-type speaker **10** according to the present embodiment. FIG. **2**(A) is a front view of the plane-type speaker **10**, and FIG. **2**(B) is a side view of the same. FIG. **3** is a partially-enlarged side view of the plane-type speaker **10**.

The plane-type speaker **10** includes piezoelectric films **20**R and **20**L, an exciter film **30**, an oscillation plate **40**, and flame members **50**. The piezoelectric films **20**R and **20**L are constituted by the same component, but they are attached to the exciter film **30** at different positions. Accordingly, they will be described in detail regarding their structure, with respect to the piezoelectric film **20**L.

The piezoelectric film **20**L includes a base film **200** having a rectangular shape in a plan view, and electrodes **201** formed on the opposing both main surfaces of the base film **200**. The base film **200**, which is a film having piezoelectricity, is preferably formed from a polylactic acid (hereinafter, referred to as a PLA) or a PolyVinylidene DiFluoride (hereinafter, referred to as a PVDF). More preferably, the base film **200** is formed from a PLA. By forming the base film **200** from a PLA, it is possible to make the base film **200** have significantly-higher optical transparency. If the base film **200** is to be used in such a manner as to induce no problem even when the base film **200** has poor optical transparency, it is also possible to employ a laminated-layer member formed from PVDF films having smaller thicknesses or a laminated-layer member formed from PLA films having smaller thicknesses. By doing this, it is possible to increase the apparent piezoelectric constant of the piezoelectric film, thereby enabling reduction of the voltage for driving the piezoelectric film. When the base film **200** is formed from a PLA, it is preferable to cut it such that each of the outer peripheral sides thereof forms an angle of about 45 degrees with respect to the direction of drawing, in order to form the base film **200** to have a rectangular shape.

The electrodes **201** are formed substantially entirely on the both main surfaces of the base film **200**. Preferably, the electrodes **201** are mainly formed from a tin-doped indium oxide (ITO), a Zinc oxide (ZnO), or a polythiophene. By employing these materials having higher optical transparency, in combination with the base film **200** formed from a PLA, it is possible to realize the piezoelectric film **20**L which is substantially transparent (with a visible-light transmittance of about 95%) or more transparent. Further, the electrodes **201** can be also constituted by silver-nanowire electrodes and, more preferably, the electrodes **201** are constituted by vaporized-aluminum electrodes, provided that they are to be used in such a manner as to induce no problem even when they have poor optical transparency. Lead-out wiring conductors, which are not illustrated, are connected to the electrodes **201**, such that sound-releasing driving signals from the outside are applied to the respective electrodes **201** through these wiring conductors.

The exciter film **30** has a rectangular shape in a plan view and is made to have a size enough to place the piezoelectric films **20**R and **20**L thereon with a predetermined interval interposed therebetween. The exciter film **30** is formed from a Polyethylene terephthalate (PET). However, the exciter film **30** may be also formed from other materials, such as Polyethylene Naphthalate (PEN), polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and, further, may be formed from any insulating materials with higher optical transparency and with strengths enough to sufficiently maintain the shape of the oscillation plate **40**, regarding its functions.

For example, in cases where the base film **200** in the piezoelectric film **20**L is formed from a PLA, and the exciter film **30** is formed from a PET, it is preferable to make the exciter film **30** have a thickness of about 0.05 mm to 0.2 mm.

The piezoelectric films **20**R and **20**L are placed on one of the main surfaces of the exciter film **30** with a predetermined interval interposed therebetween. The piezoelectric films **20**R and **20**L are placed along the longitudinal direction of the exciter film **30** and are secured to the exciter film **30** through an adhesive layer **60**.

In this case, the piezoelectric films **20**R and **20**L are secured thereto such that the drawing direction thereof forms an angle of 45 degrees with respect to the short direction of the exciter film **30**.

The oscillation plate **40** has a rectangular shape in a plan view. The oscillation plate **40** has a shape which has substantially the same length in the longitudinal direction as that of the exciter film **30** and further has a length in the short direction which is larger than that of the exciter film **30**. The oscillation plate **40** is formed from an acrylic resin (PMMA). The oscillation plate **40** may be also formed from other materials, such as PET, polycarbonate (PC), PLA and, further, may be formed from any insulating materials with higher optical transparency regarding its functions.

The oscillation plate **40** is secured, at its opposite ends in the short direction, to the opposite ends of the exciter film **30** in the short direction, through the frame members **50**. The frame members **50** have an elongated rod shape and are made of a material with a high strength, such as a metal. Further, the oscillation plate **40** is secured to the exciter film **30** in its side on which the piezoelectric films **20**L and **20**R are mounted. However, the oscillation plate **40** may be also secured to the exciter film **30** in the opposite side thereof from the side on which the piezoelectric films **20**L and **20**R are mounted.

With this structure, a hollow area **100** is formed between the oscillation plate **40** and the exciter film **30**. Further, the side in which there exists the oscillation plate **40** forms the front-surface side of the plane-type speaker **10**, while the side in which there exists the exciter film **30** forms the rear-surface side of the plane-type speaker **10**.

In this case, as illustrated in FIGS. **1** and **2**(B), the oscillation plate **40** is secured to the exciter film **30**, such that it is shaped to be warped and protruded toward the opposite side (the side in front of the oscillation plate **40**) from the side in which there exists the exciter film **30** (the side in the rear of the oscillation plate **40**). Further, FIGS. **1**, **2**, **3** and **4** exaggeratedly illustrate the warpage of the oscillation plate **40**, but, in actual, the main surface of the oscillation plate **40** has a relationship closer to parallelism with the main surface of the exciter film **30**.

Further, it is preferable that the amount of protrusion due to its warpage is not large. This is because, if the amount of protrusion due to its warpage is large, namely if the amount of its flection is excessively large, the contraction and expansion of the exciter film **30**, which will be described later, are not transformed into oscillations of the oscillation plate **40** in the forward and rearward directions (in the direction orthogonal to the centers of the main surface of the exciter film **30** and the main surface of the oscillation plate **40**).

If the oscillation plate **40** being subjected to a bending stress as described above is secured to the exciter film **30**, as indicated by thick arrows **S901** in FIG. **2**(B), this realizes a state where a pulling tension is applied to the exciter film **30** along the direction which is parallel with the main surface of the exciter film **30** and, further, is orthogonal to the opposite end sides of the exciter film **30** to which the oscillation plate **40** is secured (in the short direction of the flat plate surface of the exciter film **30**).

By applying a sound-releasing driving signal to the plane-type speaker **10** which has the aforementioned structure in a state where no sound-releasing driving signal is applied thereto, the oscillation plate **40** is caused to oscillate as illustrated in FIG. **4**, thereby releasing sounds in the forward direction of the plane-type speaker **10**. FIG. **4** is a view for explaining operations of the plane-type speaker **10**, wherein FIG. **4**(A) illustrates a state at timing when the piezoelectric films **20**L and **20**R have been contracted by the sound-releasing driving signal. FIG. **4**(B) illustrates a state when no sound-releasing driving signal is being applied thereto or the sound-releasing driving signal has an amplitude of zero. FIG. **4**(C) illustrates a state thereof at timing when the piezoelectric films **20**L and **20**R have been expanded by the sound-releasing driving signal.

If an electric field in a first direction is applied to the piezoelectric films **20**L and **20**R through the sound-releasing driving signal, the piezoelectric films **200** are contracted along the direction orthogonal to the secured ends of the oscillation plate **40** and the exciter film **30** and, then, the exciter film **30** is also contracted along the direction orthogonal to its secured ends in the plane, as indicated by thick solid lines S**911** in FIG. **4**(A). This causes the frame members **50** at the opposite ends of the exciter film **30** to be attracted toward the center in the plane along the direction orthogonal to the secured ends. This causes the oscillation plate **40** to be further warped to protrude forwardly, as indicated by a thick solid line F**911** in FIG. **4**(A).

On the other hand, if an electric field in a second direction which is opposite from the first direction is applied to the piezoelectric films **20**L and **20**R through the sound-releasing driving signal, the piezoelectric films **20**L and **20**R are expanded along the direction orthogonal to the secured ends of the oscillation plate **40** and the exciter film **30**, and, then, the exciter film **30** is also expanded along the direction orthogonal to the secured ends in the plane, as indicated by thick solid lines S**912** in FIG. **4**(C). This causes the frame members **50** at the opposite ends of the exciter film **30** to get further away from the center in the plane along the direction orthogonal to the secured ends. This causes the oscillation plate **40** to be warped with a smaller amount of protrusion in the forward direction, as indicated by a thick solid line F**912** in FIG. **4**(C).

As described above, with the structure according to the present embodiment, it is possible to cause the transitions to the state of FIG. **4**(A) and the state of FIG. **4**(C), with respect to the state of FIG. **4**(B), according to the amplitude of the sound-releasing driving signal, which causes the oscillation plate **40** to oscillate along the forward and rearward directions (the direction orthogonal to the plane center of the oscillation plate **40**). Thus, sounds corresponding to the sound-releasing driving signal are released forwardly.

Further, as described above, by preliminarily applying a constant bending stress to the oscillation plate **40** being in a non-operated state and, further, by applying stresses, thereto, through contractions and expansions of the exciter film **40** (contractions and expansions thereof due to contractions and expansions of the piezoelectric films **20**L and **20**R which have been transmitted thereto), in the same direction as that of the aforementioned bending stress, it is possible to effectively oscillate the oscillation plate **40**. Further, it is possible to place the piezoelectric films **20**L and **20**R over substantially the entire surface of the plane-type speaker **10** in a plan view, which improves the low-tone output characteristics and, also, enables oscillating the oscillation plate **40** with highest efficiency with the determined area. Further, there is no need for an electromagnetic-type exciter as illustrated in Patent Document 2 as a prior art, which enables reduction of the size of the plane-type speaker **10** (reduction of the area thereof in a front view). Further, it is possible to place the oscillation plate **40** and the exciter film **30** to which the piezoelectric films **20**L and **20**R are attached, in such a way as to separate them from each other by only an amount enough to provide a slight margin in addition to the oscillation stroke of the oscillation plate **40**, in a side view. This hardly necessitates a depthwise length as illustrated in Patent Document 3 as a prior art, which enables forming the plane-type speaker **10** to have a reduced thickness.

Further, sounds are released in the side closer to the exciter film **30** with respect to the oscillation plate **40**, but, in the aforementioned structure, the side closer to the exciter film **30** with respect to the oscillation plate **40** functions as an enclosure of a semi-closed space. This can inhibit sounds emitted in the side closer to the exciter film **30** from being leaked forwardly, thereby improving the sound-quality characteristics. Also, it is possible to place, in the hollow area **100**, a sound-absorption member made of a silicon gel and the like which has flexibility enough not to obstruct the oscillation of the oscillation plate **40** and the expansion and contraction of the exciter film **30**. By using such a sound-absorption member, it is possible to inhibit sounds released in the side closer to the exciter film **30** as described above from coming around forwardly and, further, it is possible to inhibit resonant sound waves generated from the exciter film **30** from propagating to the oscillation plate **40**, thereby attaining improvement regarding the sound distortion rate. This can realize the plane-type speaker with more excellent sound-quality characteristics.

Further, in the aforementioned aspect employing a PLA, it is possible to realize the plane-type speaker with higher optical transparency and with excellent sound quality, which is suitable for aspects in which it is placed on the screen of a thin-type television, for example.

On the other hand, although the types of sound-releasing driving signals to be applied to the piezoelectric films **20**R and **20**L have not been mentioned in detail in the aforementioned description, it is possible to apply either the same sound-releasing driving signal or different sound-releasing driving signals to the piezoelectric films **20**L and **20**R. In cases where different types of sound-releasing driving signals are applied to the piezoelectric films **20**L and **20**R, it is possible to apply L-channel signals and R-channel signals for stereophonic sounds in synchronization with each other. This enables releasing stereophonic sounds through the plane-type speaker **10**.

Next, a plane-type speaker according to a second embodiment will be described with reference to the drawings. FIG. **5** is a perspective view of the external appearance of a plane-type speaker **10**A according to the present invention. FIG. **6** is a view for explaining the structure of the plane-type speaker **10**A, wherein FIG. **6**(A) illustrates a state before an oscillation plate **40**A is secured thereto, and FIG. **6**(B) illustrates a state where the oscillation plate **40**A has been secured thereto.

The plane-type speaker **10**A according to the present embodiment is different from the plane-type speaker **10** illustrated in the first embodiment, in that the oscillation plate **40**A is secured to an exciter film **30** such that the main surface of the oscillation plate **40**A is parallel with the main surface of the exciter film **30**, but is the same in terms of the other structures.

The oscillation plate **40**A is made of the same material as that of the oscillation plate **40** illustrated in the first embodiment, but it has preliminarily had a warped shape as illustrated in FIG. **6**(A). This can be realized by bending an oscillation plate with a flat main surface through thermal treatment and the like, for example.

The oscillation plate **40**A having this shape is secured to the exciter film **30** through frame members **50** such that its main surface forms a flat surface as illustrated in FIG. **6**(B), while external forces are applied thereto in the directions of thick arrows St**902** in FIG. **6**(A) such that the protrusion of its warpage is directed toward the exciter film **30**. By securing it in this state, as indicated by thick arrows S**902** in FIG. **6**(B), the exciter film **30** is pulled in the directions toward its secured ends from its center in the direction which is parallel with the main surface and, also, is orthogonal to its opposite end sides to which the oscillation plate **40** is secured. This realizes a state where stresses have been accumulated therein, similarly to in the aforementioned first embodiment.

With this structure, similarly, it is possible to offer the same effects and advantages as those of the aforementioned first embodiment. Further, with the structure according to the present embodiment, the oscillation plate **40**A can be secured therein such that its main surface is flattened, which makes the plane-type speaker **10**A have preferable appearances when viewed at its front surface, at its side surfaces and obliquely at its front side, thereby making the plane-type speaker **10**A more suitable for aspects where it is placed in the screen of a flat-panel thin-type television as described above.

Further, since the front surface of the plane-type speaker **10**A can be made to be a flat surface, it is possible to attach a flat-panel type touch panel device to the front surface of the oscillation plate **40**A, in order to make the plane-type speaker have touch panel functions. FIG. **7** is a perspective view of the external appearance of a plane-type speaker **10**A' having a touch panel device attached to the oscillation plate. The plane-type speaker **10**A' is structured by attaching a touch panel **41** to the surface of the oscillation plate **40**A (the opposite surface from its surface facing the exciter film) in the plane-type speaker **10**A' illustrated in the second embodiment. Further, it is also possible to realize the oscillation plate **40**A using a flat-panel type touch panel device.

Next, a plane-type speaker according to a third embodiment will be described with reference to the drawings. FIG. **8** is a perspective view of the external appearance of a plane-type speaker **10**B according to the present embodiment. FIG. **9** is a view for explaining the structure of the plane-type speaker **10**B, wherein FIG. **9**(A) illustrates a side surface of an oscillation plate **40**B in an exploded state, and an assembled state thereof, FIG. **9**(B) illustrate a state where the oscillation plate **40**B is secured, and FIG. **9**(C) illustrates a state where the oscillation plate **40**B has been secured.

The oscillation plate **40**B is constituted by a main flat plate **400**, and a pair of auxiliary plates **401**. The main flat plate **400** is made of the same material and has the same shape as that of the oscillation plate **40** illustrated in the first embodiment. The auxiliary plates **401** are placed on the opposite ends of the main flat plate **400** in the longitudinal direction, namely near the two end sides thereof which are orthogonal to the sides of the oscillation plate **40**B and the exciter film **30** which are secured to each other.

The auxiliary plates **401** have an elongated shape having the same length as the length of the main flat plate **400** in the short direction and having a smaller width. The auxiliary plates **401** are made of a high-performance spring material. More specifically, preferable materials of the auxiliary plates **401** include SUS301CSP, SUS304CSP, spring-dedicated beryllium coppers C1700 and C1720, spring-dedicated phosphor bronze C5210, spring-dedicated nickel silver C7701. It is preferable that the auxiliary plates **401** have a thickness of about 0.3 mm to 0.8 mm. The hardness of the auxiliary plates **401** is higher than the hardness of the main flat plate **400** and is determined depending on the size of the oscillation plate.

The auxiliary plates **401** have been preliminarily formed to have a warped shape. The auxiliary plates **401** are mounted on the main flat plate **400**, in a state where the protrusion of its warpage is toward the main flat plate **400**. Since the main flat plate **400** has lower hardness than that of the auxiliary plates **401**, the main flat plate **400** is warped in a shape conforming to the shape of the warpage in the auxiliary plates **401**. This results in the formation of the oscillation plate **40**B having a warped shape as illustrated in FIG. **9**(B).

The oscillation plate **40**B having this shape is secured to the exciter film **30** through frame members **50** such that its main surface forms a flat surface as illustrated in FIG. **9**(C), while external forces are applied thereto in the directions of thick arrows St**903** in FIG. **9**(B) such that the protrusion of its warpage is directed toward the exciter film **30**. By securing it in this state, as indicated by thick arrows S**903** in FIG. **9**(C), the exciter film **30** is pulled in the direction toward its secured ends from its center in the short direction. This realizes a state where stresses have been accumulated therein, similarly to in the aforementioned first and second embodiments.

With this structure, similarly, it is possible to offer the same effects and advantages as those of the aforementioned first and second embodiments. Further, with the structure according to the present embodiment, the oscillation plate **40**B can be secured thereto such that its main surface is flattened, similarly to in the second embodiment. Further, with the present embodiment, due to the use of the auxiliary plates **401**, which exhibit less degradation over time than that of the main flat plate **400** made of an acrylic resin or the like, for applying a bending stress, it is possible to realize the plane-type speaker capable of accumulating a bending stress therein in accordance with the design, for a longer time period.

Further, with the structure according to the present embodiment, the auxiliary plates **401** are made of the aforementioned metal material, which causes the areas provided with these auxiliary plates **401** to have no optical transparency.

In this case, piezoelectric films can be placed such that they are separated from each other as illustrated in FIG. **10**, which can realize a structure employing the piezoelectric films made of two or more materials. FIG. **10** is a view of the structure of piezoelectric films in a plane-type speaker **10**B.

As illustrated in FIG. **10**, as the piezoelectric films according to the present embodiment, piezoelectric films **20**L' and **20**R' are placed in the area in which an exciter film **30** can be viewed through an oscillation plate **40**B in a plan view, along the longitudinal direction of the oscillation plate **40**B and the exciter film **30**. Further, piezoelectric films **21**R and **21**L are placed in the opposite end areas in which the exciter film **30** cannot be viewed in the plan view. The piezoelectric films **20**L' and **20**R' have base films made of a PLA, while the piezoelectric films **21**L and **21**R have base films made of a PVDF.

PVDFs have higher piezoelectric coefficient than those of PLAs and, therefore, expand and contract more largely than PLAs, when sound-releasing driving signals with the same amplitude are applied thereto. Accordingly, by partially employing the piezoelectric films **21**R and **21**L which are made of a PVDF, as illustrated in the present embodiment, it is possible to oscillate the oscillation plate **40**B more effectively.

Further, although the piezoelectric films made of the PVDF have lower optical transparency than that of PLA, they can be placed only in the rear of the auxiliary plates **401** having no optical transparency, which can realize the plane-type speaker with optical transparency, without degrading the external appearance thereof at its front surface.

Further, since the piezoelectric films made of the PVDF which expands and contracts by larger amounts are placed in the rear of the auxiliary plates **401** with higher spring performance, it is possible to oscillate the oscillation plate **40**B more effectively.

Further, PVDFs tend to reduce their impedances to allow larger electric currents to flow therethrough, in a higher frequency range, in comparison with PLAs. However, by placing the piezoelectric films **21**L and **21**R made of the PVDF only in the relatively-smaller areas in which the auxiliary plates **401** are placed as illustrated in the present embodiment, it is possible to reduce electric power consumption.

Further, the aforementioned respective embodiments have been described by exemplifying plane-type speakers provided with an oscillation plate and an exciter film which have rectangular shapes in a plan view. However, it is also possible to employ an oscillation plate and an exciter film which have other shapes, provided that the oscillation plate and the exciter film are secured to each other at their ends opposite to each other, which can also offer the same effects and advantages.

Further, in the aforementioned description, the plane-type speaker has been described as being placed on the foreside surface (the front surface) of an image reproduction apparatus, such as a liquid-crystal television. However, it is also possible to place an image reproduction apparatus such as a thin-type television which is constituted by a liquid crystal display, an organic EL display or the like, in the hollow area generated in the plane-type speaker. FIG. **11** is a perspective view of an AV apparatus **600** employing a plane-type speaker according to the present invention. FIG. **12**(A) is a front view of the AV apparatus **600** employing the plane-type speaker according to the present invention, and FIG. **12**(B) is a side view of the same. Although, hereinafter, there will be exemplified a case of employing the plane-type speaker **10**A illustrated in the second embodiment, this structure can be also applied similarly to the plane-type speakers according to the other embodiments.

The AV apparatus **600** includes the plane-type speaker **10**A and a thin-type display **60**. The thin-type display **60** is placed in the hollow area **100**A in the plane-type speaker **10**A. In this case, the thin-type display **60** is placed such that its image-display surface is closer to the oscillation plate **40**A. Further, the thin-type display **60** is placed such that it is spaced apart from the oscillation plate **40**A by an interval corresponding to the oscillations thereof and, also, is not in contact with the piezoelectric films **20**L and **20**R. With this structure, it is possible to realize a thin-type AV apparatus with excellent sound quality. Further, since the oscillation plate **40**A has higher optical transparency, it does not obstruct the display on the screen of the thin-type display **60** (the repeatability of images thereon, for example). Further, with this structure, it is possible to eliminate the necessity of imposing a requirement regarding optical transparency on the piezoelectric films **20**L and **20**R, which enables forming their entirety from a PVDF, for example, thereby further improving the sound-quality characteristics. Further, in this AV apparatus **60**, similarly, a sound-absorption member can be interposed in the hollow area, together with the thin-type display **60**.

Also, it is possible to realize an AV apparatus with a structure having a thin-type display, such as an organic EL display, which is attached to an oscillation plate. FIG. **13** is perspective views of the external appearance of AV apparatuses **600**A and **600**B. The AV apparatus **600**A illustrated in FIG. **13**(A) has a plane-type-speaker having the same structure as that of the second embodiment, but is structured to have a thin-type display **60**A attached to the surface of the oscillation plate **40**A (the opposite surface thereof from the surface facing the exciter film). The AV apparatus **600**B illustrated in FIG. **13**(B) has a plane-type-speaker having the same structure as that of the second embodiment, but is structured to have a thin-type display **60**A attached to the back surface of the oscillation plate **40**A (its surface facing the exciter film).

Further, it is also possible to constitute the oscillation plate by a thin-type display. FIG. **14** is a perspective view of the external appearance of an AV apparatus **600**C. The AV apparatus **600**C illustrated in FIG. **14** has the same basic structure as that of the second embodiment, but it employs an oscillation plate **40**A' which also serves as a thin-type display. Namely, the AV apparatus **600**C is provided with the oscillation plate which is constituted by a thin-type display.

With these structures illustrated in FIGS. **13** and **14**, similarly, it is possible to realize thin-type AV apparatuses with excellent sound-quality characteristics.

DESCRIPTION OF REFERENCE SYMBOLS

10, **10**A, **10**A', **10**B: Plane-type speaker
20L, **20**R, **20**L' **20**R', **21**L, **21**R: Piezoelectric film
30: Exciter film
40, **40**A, **40**B: Oscillation plate
40A': Thin-type display/oscillation plate
41: Touch panel
50: Frame member
60, **60**A: Thin-type display
100: Hollow area
200: Base film
201: Electrode
400: Main flat plate
401: Auxiliary plate
600, **600**A, **600**B, **600**C: AV apparatus

The invention claimed is:

1. A plane-type speaker comprising:

a piezoelectric resin film having electrodes on opposed surfaces thereof;

an exciter film having a main surface upon which the piezoelectric film is mounted; and

an oscillation plate having a surface which is warped in a state where the oscillation plate is not secured to the exciter film, and, when the oscillation plate is secured to the exciter film, the surface of the oscillation plate has a flattened shape with respect to the main surface of the exciter film and a constant stress is applied to the oscillation plate in a non-operated state such that a pulling tension is applied to the exciter film when the plane-type speaker is in the non-operated state.

2. The plane-type speaker according to claim **1**, wherein

the oscillation plate comprises a main fiat plate and an auxiliary plate mounted to the main flat plate, the auxiliary plate having a smaller width and a higher rigidity than that of the main flat plate, and

the auxiliary plate having a warped shape in the state where the oscillation plate is not secured to the exciter film.

3. The plane-type speaker according to claim **2**, wherein

the piezoelectric resin film comprises a plurality of individual piezoelectric resin films which are divided into a first set of individual piezoelectric resin films in an area which is overlaid on the auxiliary plate, and a second set of individual piezoelectric resin films in an area which is not overlaid on the auxiliary plate, and

a first resin of the first set of individual piezoelectric resin films is different from a second resin of the second set of individual piezoelectric films.

4. The plane-type speaker according to claim **3**, wherein

the exciter film, the oscillation plate and the electrodes are made of a material with optical transparency, and

the first resin is a polylactic acid, and the second resin is a PolyVinylidene DiFluoride.

5. The plane-type speaker according to claim **1**, wherein the piezoelectric resin film comprises a plurality of individual piezoelectric films, the plurality of individual piezoelectric films being divided in a direction parallel to the main surface of the exciter film and secured along opposite end sides of the exciter film.

6. The plane-type speaker according to claim **1**, wherein the piezoelectric resin film is PolyVinylidene DiFluoride.

7. The plane-type speaker according to claim **1**, wherein

the exciter film, the oscillation plate and the electrodes arc made of a material with optical transparency, and

the piezoelectric resin film is a polylactic acid.

8. The plane-type speaker according to claim **1**, further comprising a sound-absorption member between the oscillation plate and the exciter film.

9. The plane-type speaker according to claim **1**, further comprising a flat-plate type touch panel on the oscillation plate.

10. An AV apparatus comprising:

the plane-type speaker according to claim **1**; and

an image reproduction apparatus on the oscillation plate.

11. An AV apparatus comprising:

the plane-type speaker according to claim **1**, and

wherein the oscillation plate forms an image reproduction apparatus.

12. An AV apparatus comprising:

the plane-type speaker according to claim **1**, and

an image reproduction apparatus between the exciter film and the oscillation plate of the plane-type speaker.

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